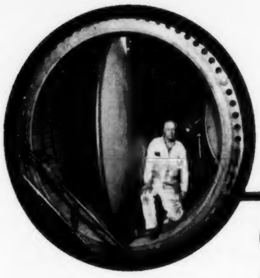


VOL. IV, No. 2
SUMMER, 1956

PUBLISHED
QUARTERLY

RESEARCH TRENDS

CORNELL AERONAUTICAL LABORATORY, INC.
4455 GENESEE ST. BUFFALO 21, N. Y.

MOBILE DYNAMOMETER *for* TIRES...

by WILLIAM CLOSE and ALBERT G. FONDA

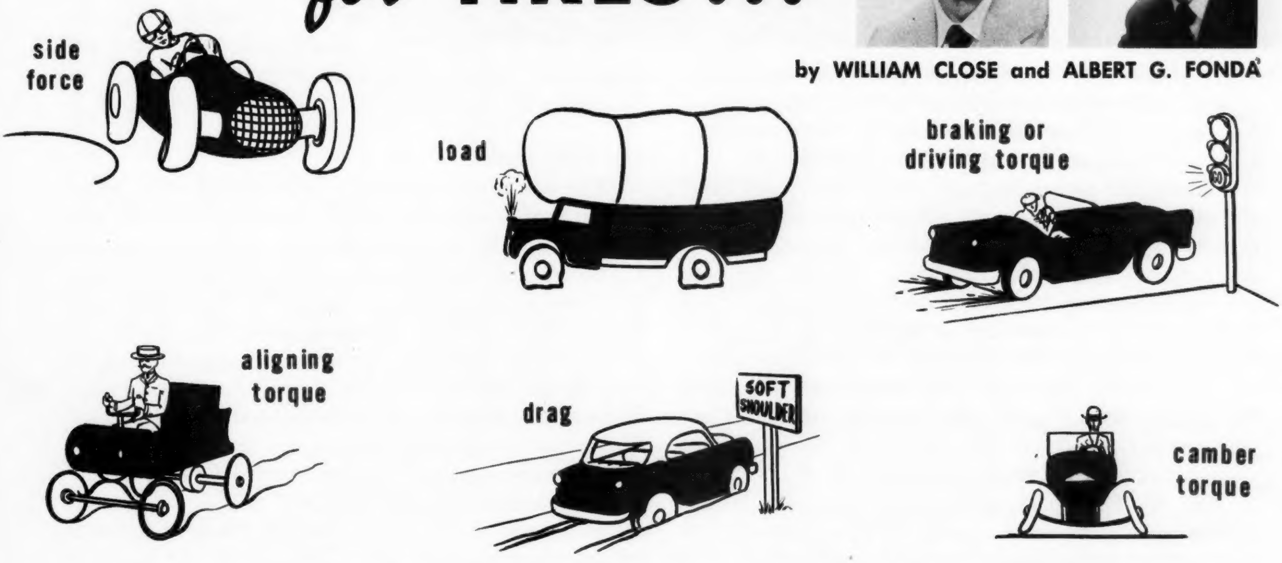


FIGURE 1 — Forces and moments which act on a moving tire. C.A.L. dynamometer produces data on tires operating under such conditions.

THE pneumatic tire is an indispensable servant of modern man; both automobiles and airplanes, important in today's civilization, would be rather impractical without it. Yet, this indispensable tire is a mysterious servant; there is insufficient data on what it does and only the barest theory on how it performs. The behavior of a rolling tire guiding a vehicle on its path is influenced by many factors of construction, use, and environment in ways not yet explained.

Automotive and aeronautical engineers are currently attacking this mystery in search of tire data and tire theory which would lead to improvements, both in vehicles and in tires. If tire performance limits could be raised, airplanes could take off and land faster, maneuver more rapidly on airports, operate better from carriers; cars could handle more easily and ride better with less danger of skidding; trucks could cruise faster and more safely and not jackknife so easily in emergencies.

Tire data are needed both for vehicle behavior studies and for developing tire theory. Through its research on aircraft dynamic stability, and similar research on automobiles, the Flight Research Department of Cornell Aeronautical Laboratory became aware of this need. As a result, a dynamometer for investigating tire behavior has been designed and built for the U. S. Air Force by C.A.L. It is currently being operated as a test facility, furnishing data both on automotive and aircraft tires, not only for the Air Force but also for tire manufacturers, and other interested companies.

Dynamometer Produces Data

Apply a side force to a rolling pneumatic tire and the tire "crawls" laterally, following a path which is at an angle to the wheel. The crawl or "slip" angle increases with the side force until eventually a skid exists. Thus the tire is similar to an airfoil, which develops more lift with increasing angle of attack until it stalls. It is the slip angle, the "angle of attack" of the tire, which is experimentally imposed upon tires. The C.A.L. dynamometer produces data consisting of the relations between slip angle, side force, load, and the other forces and moments illustrated in Figure 1. These relations are affected by the various test variables

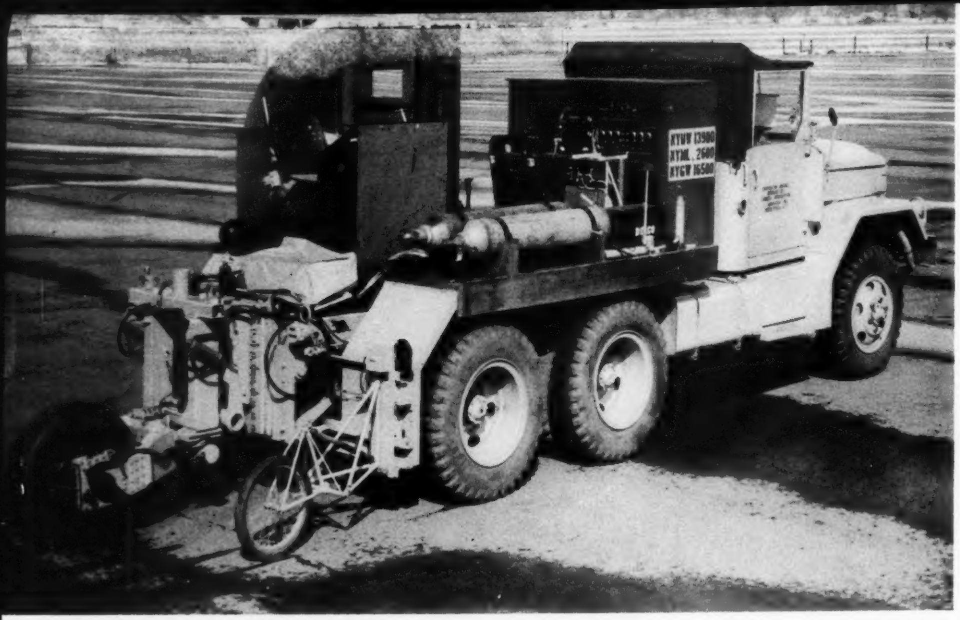
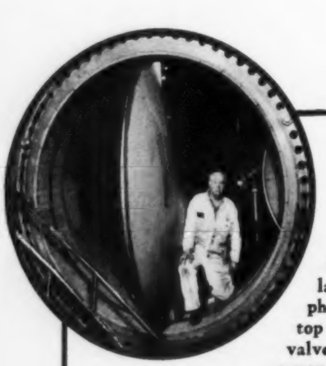


FIGURE 2—C.A.L. tire tester, consisting of an instrumented, single-wheel rig pulled behind a tow truck, is shown on Laboratory grounds.

such as tire size, construction, material, rim width, camber (tilt) angle, speed, road surface, and weather. The many possible combinations of test conditions form a virtually unlimited field for investigation.

Most other dynamometers are of the drum type, with the tire pressed against a large drum instead of a roadway. This unrealistic condition limits them to comparative and endurance tests. A few flat-road dynamometers exist, but only the C.A.L. machine will measure all six components at highway speeds (up to 60 miles per hour). Development of C.A.L.'s tire-tester was a complex job; 6300 man-hours were required for design, drafting and analysis alone, and numerous conferences were held with the U. S. Air Force and various tire and automobile companies.

The Air Force contract specified that the dynamometer must handle tires up to thirty inches in diameter, apply a maximum vertical loading of three thousand pounds, and hold the tire in various attitudes on the road surface. Steer and camber ranges of plus or minus thirty degrees were desired, well beyond the limits of any previous dynamometer. Structural rigidity was of vital importance in such equipment, and quick changing of the test tire was obviously desirable. Many arrangements were investigated before development of the final and successful machine illustrated in Figure 2.



THE COVER

C.A.L. employee standing beside an 8-foot butterfly valve in the large wind tunnel, is shown in the photo-insert at left, as well as at the top of the cover page. The large valve is located in the auxiliary flow removal ducting in the 8-foot transonic tunnel being provided by the modification program now in progress. The photo was taken during construction; additional ducting will be bolted to the flange and will be used to isolate this part of the circuit from the rest of the tunnel. C.A.L.'s facility is a variable-density, closed-circuit wind tunnel capable of operating from ½ to 2½ atmospheres total pressure. Originally designed with an 8½ by 12-foot test section and a 0.95 Mach number limit, the tunnel is now being modernized and soon will operate with an 8 by 8-foot test section over a continuously variable transonic speed range. The addition of 16,000 horsepower will double the tunnel's power.

The Final Machine

The test wheel is carried aft of the truck by means of a complex assembly which both controls the tire and measures its behavior. Success of the tire-tester as a measuring device depends on the use of wire resistance strain gages: short lengths of very fine wire cemented to suitable structural members. Both the wire and the structural members deform when loads are applied and instruments detect resulting changes in electrical resistance as measures of the applied loads. There are twenty such strain gages on five deforming members appropriately located near the tire.

Over a dozen special wheels of various widths and diameters are available, any one of which will mount on the removable hub unit. The core of the hub does not rotate and is detachably mounted at each end to a load cell, illustrated in Figure 3. Axial force bends a single beam giving side-load readings; similarly, each load cell incorporates beams giving vertical and horizontal axle-tip force readings. The sum of the cell readings represents load or drag while the difference represents aligning or overturning torque. Braking torque at present is zero, but a brake installation is being built in which additional strain gages will yield readings of this torque.

The load cells are mounted at the ends of a fork-shaped frame, carried by a trunnion in which the frame can be tilted to vary camber angle. The trunnion also allows the tire to follow road contours.

This assembly is carried beneath a rectangular frame which rotates for steering, and which can be adjusted up or down. The success of the apparatus as a test mechanism depends not only on its rigid construction (to maintain orientation and to avoid vibration), but also upon the versatility of the positioning adjustments and hydromechanical controls.

Steering is hydraulic; controlled by the operator at the aft console, as is the pneumatic loading and lifting of the test wheel. Load is easily varied with a pressure regulator and is very steady because of the inherent low

spring rate of such a system. High pressure nitrogen bottles supply this system, which includes a provision for tire inflation.

During tests with the tire steered, the truck, despite its weight, crabs along the road. Attached to its right rear corner is a specially designed, free-trailing wheel with an angle-sensing instrument on its vertical pivot. The difference between the applied steering angle (tire to truck) and the truck crab angle (free-trailing wheel to truck) gives the true steering angle of the test tire relative to the road.

The five force-and-moment electrical signals are derived from the strain gages already mentioned. In addition, four motion signals exist: steer angle and truck crab angle (the difference of these being slip angle), pitch or bounce angle, and wheel revolutions. The latter is obtained from a coil pickup passed once per revolution by a magnet on the hub. The former signals come from angle-measuring instruments which are accurate versions of the ordinary "volume control" potentiometer. An oscillograph makes a continuous photographic record of these nine signals, with room for many future additions. In addition, both movies and noise recordings of the test tire have been made for industrial customers. In the first year of operation, data tests have been made for Dunlop, Firestone, Goodrich, and General Motors.

This completes a description of the C.A.L. mobile dynamometer for tires. Now let us watch it in action.

Dynamometer in Action

The big yellow test rig is parked in Cornell Lab's hangar at the Buffalo Airport, among a dozen or more assorted airplanes. When you arrive, the project engineer and the driver-mechanic have already spent a half-hour checking and setting the equipment and making preliminary records. Ten colored lights arrayed across the instrument shelf show that the equipment is activated.

The driver sits waiting in the cab; you climb past him to a seat located amidships. The engineer checks to make sure that your seat belt is fastened, hands you an intercom microphone and earphones, then sits down at the control console.

While the truck is proceeding to the highway test strip, the engineer lowers the test wheel; it gives a sudden short screech. He tells you he is warming it up at a moderate overload. He operates another valve, and the free-trailing wheel drops to the ground.

First Test Run

Soon the truck reaches the test strip. It is straight for a mile, flat, smooth blacktop. The engineer flips a switch; in front of you on the instrument shelf, relays click and green lights go out. Paper moves in the oscillograph, making a record of the signals for zero side force and slip angle.

At the end of the test strip, the truck pulls into a gas station where the engineer checks tire pressure with a special, highly accurate gage. This tire, the engineer points out, is on a 14-inch rim scheduled for the 1957 models; it does look small, but only because it is behind the large truck. The next test will be a routine evaluation of the "cornering stiffness" (side force per unit slip angle) for three different pressures at rated load, and three loads at rated pressure.

No sooner said than done — almost. You are surprised by the seeming simplicity of the actual tests. The driver accelerates the truck to about 35 miles per hour.

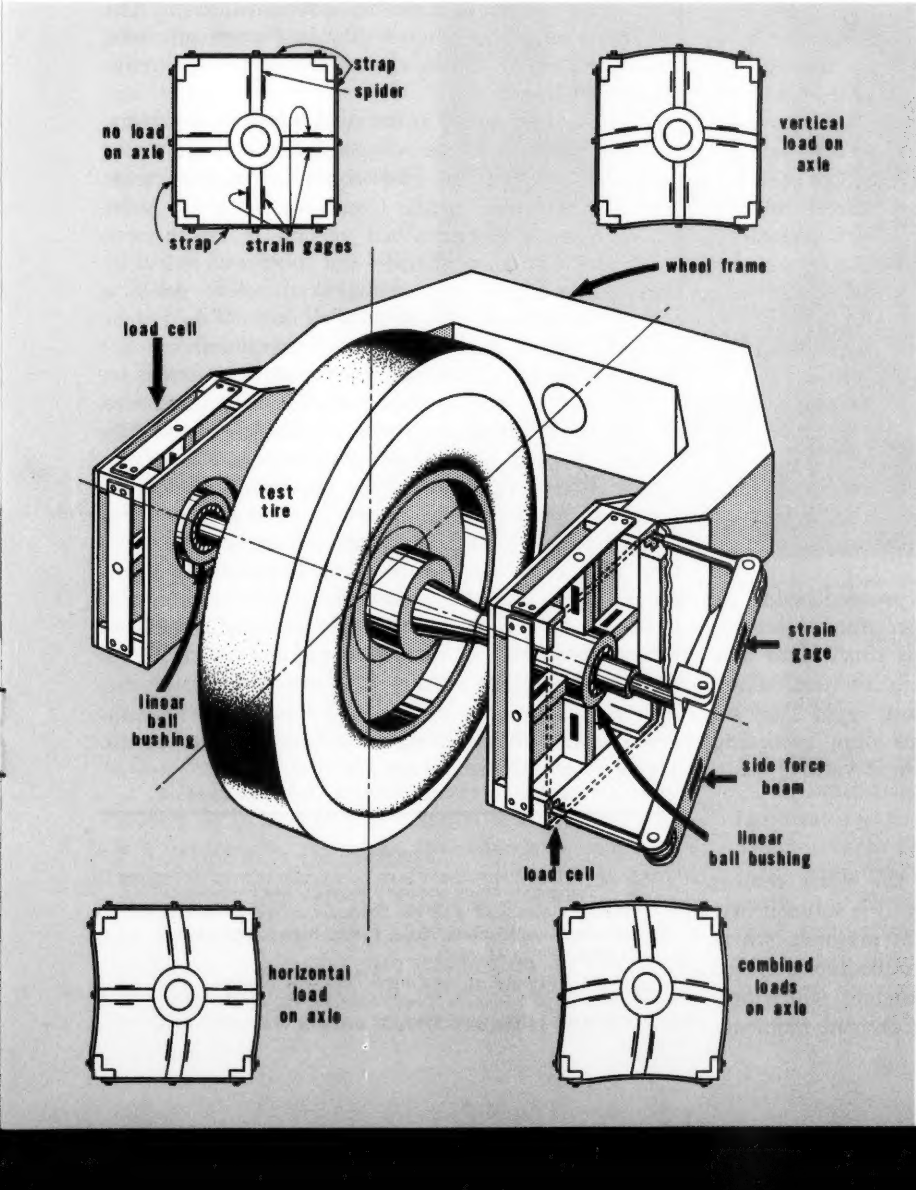


FIGURE 3—Schematic view of load cells and test tire. Sketches at top and bottom show how load cells "read" loads on axle.

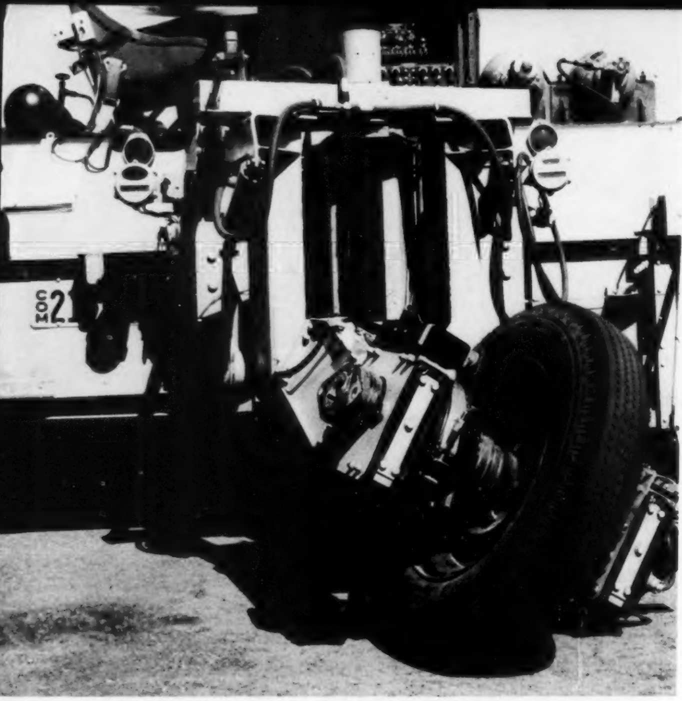


FIGURE 4 — Rear view of tire tester showing tire cambered and steered to extreme angles.

Tire behavior depends mostly on the geometry and flexibilities involved in tire "crawl," rather than on the speed at which it occurs. After starting the recorder, the engineer steers the tire slowly to an angle of only three degrees — enough to be visible on a large protractor, but not enough to make the tire squeal — back to zero, three the other way, and to zero again.

After each run, a change is made in the tire pressure or load. In half an hour the tire is completely tested, but it does not even look worn. Automatic recording makes this possible; some other testers take longer and produce enough tire wear to affect appreciably the behavior of the tire.

Back again at the gas station, the driver detaches the hub assembly and changes tires. This time we will test a lean, rounded motorcycle tire to find out if the tilting of a motorcycle gives tires any better cornering ability. This investigation is part of C.A.L.'s internal research program to explore the uncharted fields of tire behavior. Several special test conditions have been chosen from earlier tests on similar motorcycle tires.

The truck moves off and we proceed much as before, except that camber and bigger steer angles are used and the tire really squeals this time. This is a rough workout, and the tire leaves a black streak along the highway. Wear is certainly more rapid than on the 14-incher, but not too rapid to allow recording enough good data. More tests follow at various loads, pressures, and cambers.

Reduction of Data

When the tests are completed, the truck returns to the hangar. The oscillograph record is subsequently processed and put into a projection machine, where the data are read off. The result is thousands of punched cards to be fed into a computing machine which produces printed tabulations of the forces and moments. The tabulations are then plotted, point by point, against true steering angle. Correction for the tilt of the measurement axes is made when necessary. The engineer checks the plotted results for validity; then the engineer or the client, or both, convert the data into commentary on the behavior of tires to be used as the customer sees fit.

Eventually, everyone's results should fit together into a working theory on tire behavior; even now, the behavior of tires too big to test can be estimated with some success from tests of smaller sizes. This technique has been developed by the U. S. Air Force using models which exhibit predictable nosegear shimmy. Shimmy, which is only an annoyance on grocery carts, is a serious problem for airplanes. C.A.L. has recently started an Air Force contract to investigate the dynamics of a nosegear tire in use on several of today's jet fighters. It will be the first full-scale highway research on the time-variant behavior of tires, and a major step forward.

New Equipment Foreseen

In addition to giving direct results, the program will require new test equipment, including the brake installation and more elaborate instrumentation. The developed testing techniques may lead eventually to a dynamometer for testing the very highly loaded tires of modern bombers.

Huge and expensive as the latter machine would be, it would have many research possibilities and it would suggest many questions. How could we check behavior of tires at extreme speeds? Could we reach 120 miles per hour with a streamlined version of the present tester—built on a bus chassis—and could we control it? Would a wingless airplane take us safely down a runway for tests at 150 miles per hour? Would it be practical to use the Air Force's rocket sleds at 300 miles per hour? (Tires have been endurance-tested on a drum at that speed.) Could the roadway be moved past the tire? Should we plan on radically different tire designs? Maybe, no tires at all?

Not likely, that last one. The air-filled flexible doughnut known as the pneumatic tire is too useful to be outmoded, at least until civilization fills every acre of surface and sends all transportation below ground or in the air. Meanwhile, the pneumatic tire is bound to become increasingly important. A vital part in the growth of its importance will be knowledge and understanding of the details of its dynamic behavior. These will be gained by intensive scientific research which began its vigorous infancy in the Cornell-USAF mobile dynamometer for tires.

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"Preliminary Study of Some Theoretical and Experimental Problems Associated with the Dynamics of the Automobile and Its Tires," Infanti, Nello; C.A.L. Report YA-804-F-1; August, 1952; 43 pages.

"A Discussion of the Lateral Force and Moment Characteristics of Pneumatic Tires," Andrews, H.; C.A.L. Report TB 902-F-1; February, 1954; 38 pages.

TIME and TEMPERATURE Gremlins of DESTRUCTION...

by LUKE A. YERKOVICH

Can we make a missile which will go 20,000 miles an hour? If the "bird" is to fly in a very rarefied atmosphere, we can answer unequivocally yes. If it is to fly in denser atmospheres, such as in the troposphere below 50,000 ft., we probably cannot — at least not today.

The major difficulty confronting a missile in attaining high speed in dense atmospheres is aerodynamic heating resulting from the passage of air over the surface of the missile. Surface temperatures may reach several thousand degrees after a few seconds of this friction. Unfortunately, modern technology has not yet developed materials able to withstand the severe conditions of hypersonic flight. This problem is well recognized and many research programs are now in progress to develop stronger, more heat-resistant materials.

C.A.L. engineer readies test specimen in furnace for determining creep behavior and establishing design limitation of alloys.

C.A.L.'s Studies

The Materials Department of Cornell Aeronautical Laboratory has been active for eight years in studies for the U. S. Air Force and the U. S. Navy Bureau of Aeronautics, developing alloys and precision testing techniques on alloys, missiles, and aircraft. C.A.L.'s materials study has been particularly concerned with the behavior of structural members when they are exposed to load and heat. Either one of these elements can destroy the integrity of a structure but when they are combined they become even more destructive, through a damaging process called "creep."

Stresses are the internal forces in a material which are set up in response to external loads. Creep, then, is a progressive, relatively slow change in shape of a material under stress at high temperature. It can be illustrated simply by the behavior of a tar pavement on a warm sunny day. The pavement moves slowly under the weight of a man standing on it. The longer he stands on one spot, or the more force he applies on that spot, the greater the movement. The pavement does not move thus on a cool, cloudy day; this indicates the role heat plays in creep.

"High temperature," when used in reference to creep, is likely to be a different thermometer value for different materials: the melting point of the material in question is an important reference mark. Mercury, for example, which melts at —38°F, may creep at —75°F, and lead, which melts at 621°F, may creep an equal amount at 70°F, while tungsten, which melts at 6170°F may not creep as much at 2000°F as mercury or lead did under the above conditions.

C.A.L.'s metallurgists have studied the creep behavior of aircraft materials under conditions simulating actual use. These studies have involved measuring the strain (the deformation of an elastic or plastic material caused by stress) observed in materials exposed to periodic temperature and stress interruption, periodic overheating and over-stressing, and fluctuating stress. Materials tested have included the light alloys, magnesium and aluminum, which can be used from 200°F to 400°F; intermediate temperature alloys such as AISI 4130 stainless steel, from 800° to 1200°F, and super-alloys of the cobalt, nickel and chrome variety, from 1200° to 1800°F. Studies on high temperature titanium alloys applicable up to 1000°F, also have been performed.

Effects of Temperature

All materials creep under certain conditions of temperature, stress, and time of stress application. Their strength behaviors, therefore, must be defined in these terms when they are intended for high temperature use. However, to appreciate the significance of these factors on the properties of materials we must understand their effects on the tensile stress-strain relation of the material in which we are interested.

Let us disregard the time factor and see what

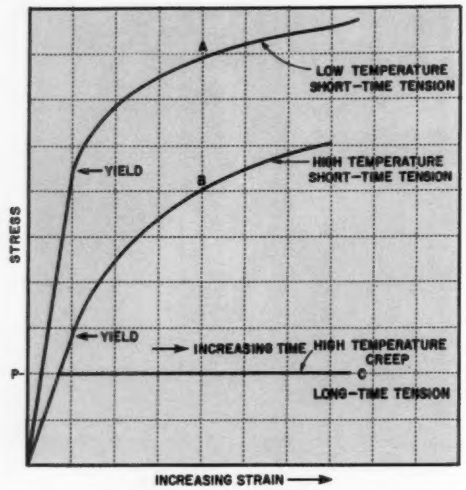

FIGURE 1 — Effect of temperature and time on the strength characteristics of metals.

temperature does to a typical engineering material. In Figure 1 we see that the material at both low and high temperatures (curves A and B) displays similar characteristics: it has a measure of elasticity (elastic modulus), a yield point and a tensile strength — mechanical properties essential to design. In this illustration however — and this is extremely important — high temperature substantially reduces all three of these properties.

Another difference resulting from high temperature is the variation in the stress-strain behavior as it correlates with rate of strain. The same material tested at high temperature but under different rates of strain, would also illustrate this variation.

At low temperatures, this behavior remains about the same unless strain rates approaching impact velocity (high rates of loading) are applied. At high temperatures on the other hand, the material responds to strain rate — so much so, in fact, that the portion of the curve beyond the yield point will be altered completely with a small increase in strain rate, and thereby make the material appear to be stronger.

Effects of Time

Because tensile tests are conducted in a relatively short period the effects of time are minor compared to the effects of temperature. However, if temperature and stress are favorable for promoting creep, time effects may be important in the deformation process. For example, in Figure 1, if the material at low temperature (curve A) is stressed to a value P within its elastic limit, and this state of stress is maintained for some time, very little creep will be detected, so little in fact, as to be almost undetectable. When stress is removed, the material will just about assume its original dimension.

On the other hand, if the material is stressed equally at high temperature (curve B), still within the elastic limit, creep will occur just as long as the stress remains applied (curve C).

Furthermore, this time-dependent strain will follow a characteristic pattern. Once creep has occurred, the material will never again assume its original dimensions, even after stress is removed. If both high temperature and stress persist, rupture induced by creep will eventually result.

The Creep Pattern

Although the effectiveness of temperature, stress, and time in promoting creep depends upon the material, creep does follow a distinctive pattern. It is best illustrated by relating deformation to time at a specific temperature under the influence of various constant stresses, as shown in Figure 2.

Except that the curves are displaced on the time and deformation scales, they display four common characteristics: (1) an initial extension, upon application of load, which consists of elastic deformation and possibly plastic deformation, (2) a stage of decelerating creep rates encountered immediately after loading, called primary creep, (3) a stage of approximately constant creep rate referred to as secondary creep, (4) a stage of accelerating creep rate known as tertiary creep, which leads to rupture.

These four characteristics may have a bearing on the temperature, stress and time limits which can be tolerated. We must avoid materials in which primary creep is dominant. The secondary creep stage appears to be most important because data gathered during this stage can be easily applied in design.

Improving Creep Resistant Properties

Although creep has been studied intensively, little is known about how it occurs. Metallurgists have found that certain metallurgical techniques can be used advantageously to inhibit it. Solid-solution strengthening and precipitation hardening, alloying and metallurgical processes producing the best kind of interlaced pattern of metal crystals, are most beneficial and widely used today.

Creep, besides being sensitive to temperature and stress, is extremely sensitive to structure. To derive the benefits of alloying, metallurgical reactions asso-

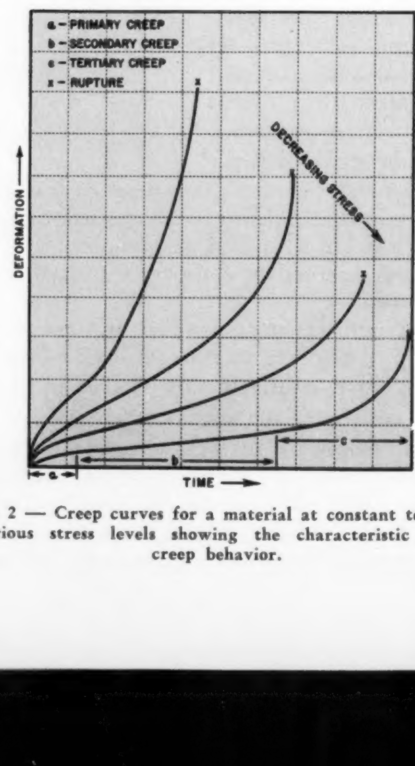

FIGURE 2 — Creep curves for a material at constant temperature and various stress levels showing the characteristic stages of creep behavior.

ciated with it during exposure must be insensitive to the conditions promoting creep. Thus, precipitation hardening and the reluctance of the precipitate to alter its form account for the fact that a material, such as Inconel X, has creep properties superior to those of the same base material Inconel.

On the other hand, wrought Inconel's susceptibility to metallurgical change accounts partly for its inferior creep resistance when it is compared with cast Inconel at high temperature.

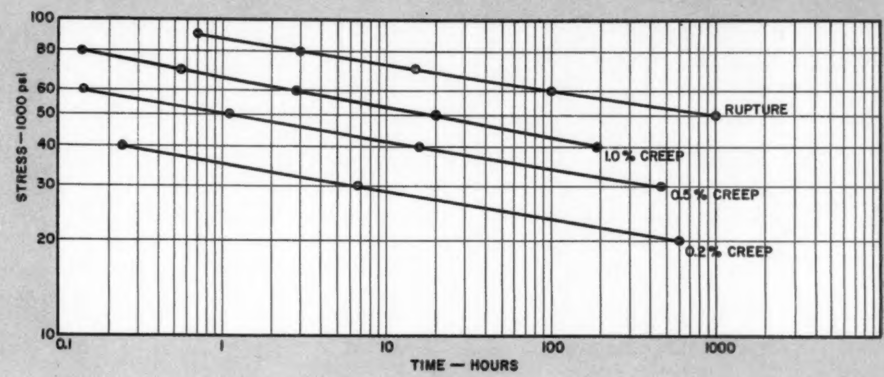

FIGURE 3 — Stress-time design chart at a single constant temperature for selecting limiting stress values.

Alloying is one way of improving creep resistance, but by no means the only one. Commonly used today are such procedures as hot-cold work, heat treatment, and grain coarsening, all of which may be somewhat effective, depending upon temperature of exposure of the metal and the tendency of the metal to be stable.

Creep Data Necessary

In the short interval of ten years, major progress has been made in aircraft propulsion systems. However, engine operating temperatures have risen from approximately 900°F to 1600°F and thus have called for better heat-resistant materials. Metallurgists have met this challenge, as evidenced by the many high temperature materials which are now available.

Precision creep testing techniques have been developed to familiarize metallurgists with the factors causing creep. Along with some conventional creep testing devices by which metallurgists can get a complete recording of creep history of materials from the time the test starts until rupture occurs, C.A.L. has developed techniques for measuring the creep properties of materials under compression, bearing and sheer stresses and also has modified conventional tensile testing equipment to simulate the temperature and stress conditions actually encountered in flight.

Reliability of data depends mainly on the temperature specifications of the test and the control of temperature throughout the test. Accordingly, it is not uncommon to find maximum temperature fluctuation limits of ± 5°F specified at nominal temperatures as high as 1800°F for several thousand hours.

Recommended practice, however, regarding the length of tests, depends mostly on the anticipated service life of the material. Therefore, data on materials for relatively short time service (from a few to about 100 hours) would interest the aviation industry, whereas data up to 100,000 hours would interest oil refining plants and central power stations.

In either case, the stringent requirements of the test must be maintained and the conditions of the test and material must be indicated. In practice, creep and rupture behavior are generally surveyed over a time range by conducting tests at individual constant temperatures but at different stresses.

Information is consolidated into stress-time, design-type charts (Figure 3), to define limiting stresses for various degrees of deformation or rupture. Such charts reduce the errors of individual tests, and permit reliable interpolation of limiting stresses between test points for constant-temperature, constant-stress operation.

Information provided by this design chart must be applied with reservation because tests are performed under controlled conditions. In aeronautical research, data must be adjusted to fit the needs of intermittent and fluctuating temperatures or stresses encountered in flight. Because of the variations of properties in materials, the designer usually designs to stress values below those dictated by the design chart. This margin of safety results in increased and perhaps unnecessary weight, however, which can affect aircraft performance detrimentally.

From C.A.L.'s studies, generalizations regarding creep accelerations and delays have evolved. It has been found that, so far as rupture is concerned, materials do not behave the same way in simulated flight testing as they do in conventional static creep testing. It also has been found that the designer must be concerned not only with stresses which have been built into the airplane or member, but also with stresses which are induced due to the thermal gradients.

From these generalizations, constant-load, constant-temperature data which is made available can be refined. The end product will, of course, be aircraft and engine elements operating at maximum efficiency.

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"Effect of Cyclic Load Frequency on the Creep-Rupture and Fatigue Properties of Jet Engine Materials," Yerkovich, Luke A.; Guarnieri, Glen J.; C.A.L. Report KB-811-M-17; June, 1955; 74 pages.

"Intermittent Stressing and Heating Tests of Aircraft Structural Metals, Part II," Guarnieri, Glen J.; C.A.L. Report KB-685-M-14 (WADC TR 53-23); May, 1954; 91 pages.

"Intermittent Stressing and Heating Tests of Aircraft Structural Metals, Part III," Guarnieri, Glen J.; C.A.L. Report KB-892-M-7 (WADC TR 53-24); June, 1955; 65 pages.

Recent C. A. L. PUBLICATIONS

Requests for copies of the following unclassified reports should be directed to the Editor. Distribution of some of these publications requires approval of the sponsor.

"AN INERT GAS INSTALLATION FOR AIRCRAFT FUEL TANKS," Naulty, Howard W.; reprinted from Aeronautical Engineering Review; 8 pages; December, 1948.

A method of reducing the oxygen content of the space above the liquid in aircraft fuel tanks below that point sufficient to sustain combustion is described herein.

"AN INVESTIGATION OF THE RAIN EROSION OF TRANSPARENT AIRCRAFT GLAZING MATERIALS AT SUBSONIC SPEED," Lappi, Roy R., Stutzman, Raymond H., Wahl, Norman E.; C.A.L. Report PC-743-M-106 (WADC TR 55-499); 27 pages; November, 1955.

Results of an investigation to obtain data on the rain erosion of transparent aircraft glazing materials under controlled laboratory conditions are reported.

"DEVELOPMENT OF A MINIATURE VORTEX FREE-AIR THERMOMETER, FINAL REPORT," Beneke, Jack; C.A.L. Report IH-894-P-1; 69 pages; November, 1955.

This report describes the development of a miniature vortex free-air thermometer suitable for installation on high-speed, subsonic aircraft.

"FLIGHT EVALUATIONS OF VARIOUS LONGITUDINAL HANDLING QUALITIES IN A VARIABLE STABILITY JET FIGHTER," Harper, Robert P., Jr.; C.A.L. Report TB 757-F-12 (WADC TR 55-299); 47 pages; July, 1955.

An F-94A jet fighter was modified to provide variable longitudinal stability and control characteristics, thus permitting in-flight variations of the longitudinal handling qualities. This report reviews the program and discusses pilot comments and evaluations made.

"HANDBOOK OF INSTRUCTIONS FOR EXPERIMENTALLY DETERMINING THE MOMENTS OF INERTIA AND PRODUCT OF INERTIA OF AIRCRAFT BY THE SPRING-OSCILLATION METHOD," Woodard, Claude R., Whitcomb, David W.; C.A.L. Report TB-822-F-2; 276 pages; June, 1955.

Design and construction of "standardized" test equipment for applying the spring-oscillation method to a variety of aircraft is detailed in this report.

"ON THE ATTENUATION OF A SHOCK WAVE FROM A SLOTTED WALL," Sun, T. F.; C.A.L. Report AD-844-W-4; 63 pages; August, 1953.

The primary interest of this study concerns the structure of the reflected wave pattern. It constitutes part of a continuing study of the problems of shock-wave reflection and attenuation, and of the so-called "triple-points."

"RATIONALIZED MKS SYSTEM OF UNITS," Chapman, Seville; reprinted from American Journal of Physics; 4 pages; March, 1956.

The mks system of units is explained and compared with the Gaussian system (and its components, the cgs electrostatic system and cgs electromagnetic system). It is suggested that the mks system is the easier system to use.

About the Authors...

LUKE A. YERKOVICH, born in the shadow of the great steel mills of Lackawanna, New York, determined at an early age to study metals. He carried out his ambitions at Penn State University where he received a B.S. degree in metallurgy in 1942. He received an M.S. degree in mechanical engineering from Michigan State University in 1950, where he also lectured on materials testing, heat treating, and foundry practice. He was discharged from the U. S. Navy as a Lieutenant in 1945 after three years of active duty in the Atlantic and Pacific theaters.

Before joining C.A.L. in 1950, he was assistant metallurgist for the American Brake Shoe Company of Chicago and metallurgist and product engineer for the Welding Products Division. As associate research metallurgist at the Laboratory, he supervises the high temperature phases of materials testing. His professional interests lie primarily in the development of effective mechanical testing techniques.

He is director of the regional chapter of the American Society for Metals and is a member of the U. S. Naval Reserve Material Unit.

ALBERT G. FONDA graduated from Cornell University in 1951 with a B.S. degree in Mechanical Engineering. He completed graduate work at Cornell and received the degree of M.S. in engineering in 1954.

He was employed by the General Electric Company, Schenectady, as a refrigeration and aircraft gas turbine test engineer during 1948-49. After graduation from Cornell in 1951 he joined the New Holland Machine Division of the Sperry Corporation where he performed detail design and layout of farm machinery. During the summer of 1953 he worked for the Flight Research Department of C.A.L. and conducted an investigation of the design of mechanical simulators for the study of the lateral motion of automobiles.

He joined the Flight Research Department of C.A.L. permanently in February 1954. He is project engineer on the tire tester and has conducted a series of test programs to measure tire performance characteristics for several tire manufacturing concerns. He has been recently transferred to the newly formed Vehicle Dynamics Department, part of the Full-Scale Division, where he will continue supervision of Military tire research.

WILLIAM CLOSE and his chief William F. Milliken, head of C.A.L.'s Full-Scale Division, have a common interest in racing cars as well as airplanes. In fact, Close met Milliken at the Watkins Glen Grand Prix road races in 1949. He joined C.A.L. in 1952 with a background of aeronautical experience on over 30 different types of aircraft.

Close was born in Scotland, educated at Croydon Polytechnic, Croydon, England and Medway Technical College, Gillingham, Kent. He acquired his first workshop and office experience in design and manufacture of small cars with Trojan Ltd., Croydon. He later worked for Imperial Airways and Short Brothers Ltd., Rochester, England, oldest aircraft manufacturing company in the world. In 1943 he joined de Havilland Aircraft Company and in 1947 went to Canada as a design engineer for A. V. Roe.

At C.A.L. he has worked as a design engineer on research installations in a number of airplanes and automobiles.

He is an Associate Fellow of the Royal Aeronautical Society of London, member of the Society of Automotive Engineers, the British Empire Motor Club of Toronto and the Sports Car Club of America.